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(54) Composite Structure for Floor Panels

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(57) 10 Claims

Because of their special construction, the structures according to the invention meet internationally applicable safety requirements in case of fire, for example ATS 1000.001.

The individual structural elements of the composite structure have the following functions, which they fulfil advantageously.

The E-glass cloth on the surface of each side has four main functions: (1) during lay-up of the lightweight flat structures it facilitates manipulation of the fiber composite materials; (2) the finished panel can be more simply machined; (3) a delamination of fibers during sawing is prevented; and (4) galvanic corrosion during the lifetime of the structure when used as a floor panel in aircraft is prevented.

The underlying carbon fibers impregnated with phenolic resin serve to minimize flexure of the structure when under high load, without increasing its weight, and to cover the layer of epoxy resin. The structure thereby meets internationally applicable safety requirements in case of fire, for example ATS 1000.001.

The R-glass fibers, together with the correctly chosen bonding agent, enable the epoxy resin to bond chemically to the fibers during curing. In this way a quasi-perfect interface is produced between the fibers and the matrix.

The shear stress to which the floor panel is exposed is mainly applied in the flight direction of the aircraft. Therefore the R-glass fibers can be made to run parallel to the flight direction by laying the panels of the composite structure in the L direction. However, aircraft builders often demand that the W direction of the panels coincide

with the flight direction. This facilitates construction of the floor because the dimensions of the panels are such that when so laid they are cut and glued less often so there is less waste.

Regardless of whether a panel is oriented in the L direction or the W direction, the R-glass fibers must always run parallel to the flight direction. Because the R-glass fibers are less fragile than the carbon fibers that lie perpendicular to the flight direction, and because the R-glass fibers are embedded in epoxy resin, which is less fragile than phenolic resin, this connection between the R-glass fibers/epoxy resin layer and the covering layer as well as the honeycomb core can be optimally loaded without the production of microcracks while the floor panels are in use.

This fact, combined with a precise curing reaction of the epoxy resin layer and the phenolic resin layer, ensures that no delamination occurs, either between the various layers or between the core plate and the layers. As a consequence, panels manufactured in this way have higher fatigue strength, higher impact resistance, higher shear strength and simultaneously less flexure under maximal load, with no substantial increase in the areal weight or the thickness of the lightweight flat structure.

Fig. 1 is a perspective view of a honeycomb structure with hexagonal cells; and

Fig. 2 is a cross-section of a composite structure in accordance with the invention and incorporating a honeycomb structure as shown in Fig. 1.

As shown in Fig. 1, in a honeycomb structure 1 with hexagonal cells, a T direction (thickness) defined by the direction of the longitudinal axes of the cells is indicated by 5, an L direction defined by the longitudinal direction of the ribbons comprising the honeycomb by 7, and a W direction perpendicular to both the T and L directions by 9. The honeycomb cell width is indicated by 3. In Fig. 2, the cross-section is taken in the T direction of the incorporated honeycomb structure to illustrate the construction of the composite structure.

In the invention, a core 16 comprising the honeycomb structure 1 is covered on both sides first by a carbon fiber layer 12 and then with an E-glass cloth 10, both of which are embedded in phenolic resin. Between the carbon fiber layer 12 and the core 16 is a layer of epoxy-resin-impregnated R-glass fibers 14.

This structure was manufactured as follows, with reference to Table 1, and was subjected to tests, the results of which are summarized in Table 2.

An aramid honeycomb of type ECA 3.2-96, such as is manufactured and marketed by Euro-Composites S.A., was used as the core 16. The honeycomb comprises hexagonal cells with an average width of 3.2 mm and has a nominal density of 96 kg/m³.

To each side of the core 16 were applied two layers of fiber composite materials consisting of fiber-reinforced artificial resins. In the present case two different types of fiber composite material were used:

a. The outer fiber composite material 10 comprises E-glass cloth (± 25 g/m²) and unidirectional carbon fibers 12

(± 190 g/m²), lying in the L direction in this example, both of which are embedded in phenolic resin.

b. The inner fiber composite material 14 comprises unidirectionally oriented R-glass fibers (± 260 g/m²) embedded in epoxy resin, the fibers lying in the W direction in this example.

The R-glass fibers used here have a modulus of elasticity equal to 86,000 MPa, a maximal tensile strength of 4,400 MPa and a relative density of 2.55 g/cm³. The carbon fibers have a tensile strength of 3,792 MPa, a modulus of elasticity of 234,000 MPa, and a relative density of 1.78 g/cm³. The gelling temperatures, curing temperatures and curing times of the resin systems are given in Table 1.

Table 1

	Gelling Temperature °C	Curing Temperature °C	Time (min)
Phenolic resin	120	135	90
Epoxy resin	90	135	90

The panel so produced was tested extensively and compared with a standard floor panel. The results of the two test series are given in Table 2.

Table 2

	STANDARD PANEL	PANEL ACCORDING TO THE INVENTION
Panel thickness (mm)	9.35-9.65	9.35-9.65
Areal weight (kg/m^2)	2.950-3.150	2.450-2.650
Drum peel force, W direction (N/76mm)	350-390	330-360
4-point bending force, L direction (N)	1,450-1,650	2,000-2,300
Deflection at 446 N, L direction (mm)	7-8	4-5
3-point shear force, W direction (N)	1,900-2,100	2,500-2,800
ATS 1000.001	did not pass	passed
Fatigue limit (load cycles)	850	2,450

Table 2 documents the improved characteristics of a floor panel manufactured in accordance with the invention over a standard panel.

The panel in accordance with the invention has a deflection under load of only 50% to 70% of that of the standard panel, even though its areal weight is lower by 500 g/m^2 for the same thickness.

Despite the significantly lower resin content in the panel in accordance with the invention, and despite the fact that the peeling was parallel to the fiber direction of the inner fiber composite layer, i.e. in the W direction, the reduction in peeling force between the core

plate and the covering is negligible.

Also, because of a better choice of fibers, i.e. unidirectional carbon fibers as opposed to woven E-glass, the 4-point bending force result was improved by 30% to 40%.

The 3-point shear force result in the W direction was improved by 30-35%, because of the better ratio of fiber to resin in the honeycomb of the core plate.

Furthermore, the ATS 1000.001 regulations prescribing the self-extinguishing properties, smoke density and toxicity of the smoke produced are met owing to the particular construction of the panel wherein a phenol matrix is outside and an epoxy matrix is inside. The standard panel, which was not so constructed, does not satisfy ATS 1000.001.

In addition, because of the symmetric construction of the lightweight flat structure in accordance with the invention, fewer problems with bowing of the panels are encountered during manufacture.

To simulate the life expectancy of a floor panel in the laboratory, a procedure was developed on the basis of the following assumptions.

Assume that an aircraft makes 851 flights per year, carrying an average of 210 passengers, and has two aisles, i.e. 105 passengers per aisle. The number of loadings per year will then be:

- Passengers boarding and leaving the aircraft:
105 x 2 x 851 = 178,710 loadings

- Visits to toilets plus perambulation:
  1.5 per passenger x 105 passengers x 851 flights = 134,032 loadings

- Use by flight crew, 4 persons, 16 times each:
  4 persons x 16 x 851 flights = 54,464 loadings

- Use by service trolleys:
  4 rollers x 8 x 851 flights = 27,232 loadings

The total number of loadings for the aisle region is then 394,438 per year, or 462 loadings per flight, which corresponds to one load cycle.

Table 3 shows the distribution by weight of the loadings in a load cycle for an aircraft operating in Europe and North America. These weights include a dynamic component of 15% for running, jumping, and dancing in flight.

Table 3

60 kg	2.5%	11 loadings
70 kg	5.0%	23 loadings
80 kg	15.0%	70 loadings
100 kg	25.0%	116 loadings
110 kg	35.0%	162 loadings
120 kg	10.0%	46 loadings
130 kg	5.0%	23 loadings
145 kg	2.5%	11 loadings
	Total 100%	462 loadings

Thus, for each floor panel an individually reproducible Wöhler stress-number curve can be constructed, so that a life span can be calculated for each floor panel

with reference to the associated load cycle.

The permanent deformation of the panels may not, however, exceed 1 mm.

It can be seen from Table 2 that the standard panels have a fatigue limit of only 850 load cycles; that is, their life span is about 1 year of flight operations.

In contrast, a panel in accordance with the invention, despite its lower weight, tolerates 2,450 load cycles; that is, under flight conditions its life span is about 2.9 years.

The weight saved by using the lightweight panel tested in this experiment, for an aircraft with a floor area of 228 m2, is between a maximum of (3.150 kg/m² - 2.450 kg/m²) x 228 m² = 159.6 kg and a minimum of (2.950 kg/m² - 2.650 kg/m²) x 228 m² = 68.4 kg.

The life span of a floor panel in accordance with the invention can be dramatically increased by doing without the weight savings in comparison with the standard panel. The mechanical properties of the panel in accordance with the invention can be improved simply by using a honeycomb core with higher weight per unit volume.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A composite flat structure for floor panels comprising a rigid cellular core to each of two opposed surfaces of which inner and outer layers of fiber composite materials are attached, and wherein

each of said outer layers comprises a layer of E-glass cloth and a layer of unidirectional carbon fibers both embedded in a phenolic resin,

each of said inner layers comprises a layer of unidirectional R-glass fibers which are embedded in an epoxy resin and which are arranged to lie transversely with respect to the unidirectional fibers in said carbon-fibers layer, and

said phenolic resin and said epoxy resin have substantially compatible gelling temperatures, curing times and curing temperatures so that they can be cured together.

2. A structure as claimed in Claim 1, wherein said cellular core comprises an aramid honeycomb structure formed of aramid ribbons running in an L direction perpendicularly to a W direction whilst defining honeycomb cells with longitudinal axes parallel to a T direction, which is also perpendicular to the W direction..

3. A structure as claimed in Claim 2, wherein said R-glass fibers lie parallel to the W direction of the core and said carbon fibers lie parallel to the L direction of the core.

4. A structure as claimed in Claim 2., wherein said R-glass fibers lie parallel to the L direction of the core and said carbon fibers lie parallel to the W direction of the core.

5. A structure as claimed in Claim 1, wherein the core

comprises an aramid honeycomb structure with a cell width between 3.2 and 6.4 mm inclusive and a specific density between 50 and 144 g/cm^3 inclusive, and wherein the ratio of said carbon and glass fibers combined to the phenolic and epoxy resins combined is between 83:17 and 37:63 inclusive.

6. A structure as claimed in Claim 1, wherein said phenolic resin has a gelling temperature in the range of 100°C to 120°C, a curing temperature in the range of 120°C to 155°C, and a curing time in the range of 60 min to 120 min.

7. A structure as claimed in Claim 1, wherein said epoxy resin has a gelling temperature in the range of 80°C to 100°C, a curing temperature in the range of 120°C to 155°C, and a curing time in the range of 60 min to 120 min.

8. A structure as claimed in Claim 1, wherein said R-glass fibers have a maximal tensile strength of 4,400 MPa, a modulus of elasticity of 86,000 MPa and a relative density of 2.55 g/cm^3.

9. A structure as claimed in Claim 1, wherein said carbon fibers have a maximal tensile strength of 3,792 MPa, a modulus of elasticity of 234,000 MPa and a relative density of 1.78 g/cm^3.

10. A structure as claimed in Claim 1, comprising

- a thickness between 9.35 and 9.65 mm inclusive;
- an areal weight between 2.450 and 2.650 kg/m^2 inclusive;
- a drum peel force in the W direction between 330 and 360 N/76 mm;
- a 4-point bending force for the L direction between 2,000 and 2,300 N inclusive;

- a deflection for the L direction at 446 N between 4 and 5 mm inclusive;
- a 3-point shear force for the W direction between 2,500 and 2,800 N; and
- a fatigue limit of at least 2,400 load cycles.

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PATENT AGENTS OF THE APPLICANT

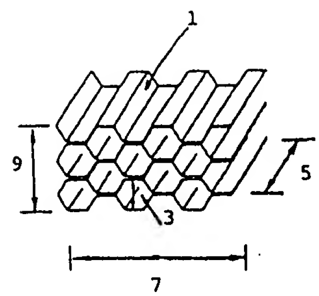

FIGURE 1

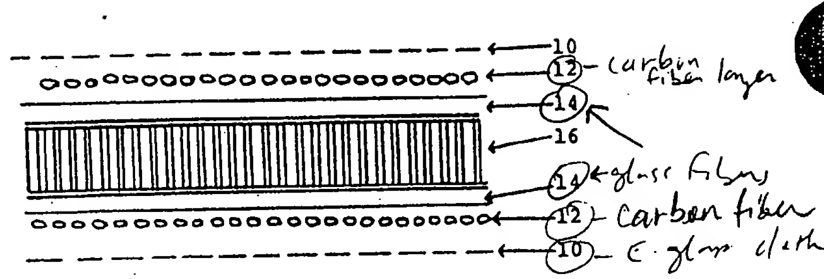

FIGURE 2